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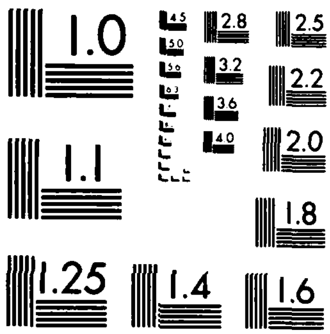


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# Superstructure Icing: Non-Suitability of Current Forecasting Aids for Navy Ships

AD-A143 304


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*Atmospheric Physics Branch*
*Space Science Division*


July 5, 1984




NAVAL RESEARCH LABORATORY
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Three currently available graphical aids (nomograms) for use in forecasting superstructure icing due to wind blown spray are reviewed for applicability to U.S. Navy vessels. It is concluded that these aids are not very suitable in their present form because they are biased toward fishing trawlers and other small displacement vessels, and they do not distinguish differences in the freeboard among various vessels. A review of ongoing and recent work in the field of superstructure icing is presented. A research plan is described and recommended for improving the applicability of available forecasting aids to U.S. Navy vessels.

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Superstructure Icing: Non-Suitability of Current Forecasting Aids for Navy Ships

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## PREFACE

This report is an outgrowth of work performed by the Naval Research Laboratory (NRL) for the Naval Environmental Prediction Research Facility (NEPRF) under work request No. N6685683WR83103 (15 October 1982). This work involved the development and documentation of computerized aids for use with the Tactical Environmental Support System (TESS) in the analysis and forecasting of aircraft icing and shipboard superstructure icing conditions. Acknowledgement is due to Mr. Sam Brand, the NEPRF Technical Representative for this project, for guidance during the course of the work. LCDR Art Trapp, officer in charge of the Naval Oceanography Command Detachment (NOCD) at the National Climatic Center (NCC) in Asheville, North Carolina, and the NOCD Technical Advisor, Mr. Brian Wallace, gave valuable assistance and advice in preliminary searches of the NCC archives for ship icing reports.

# SUPERSTRUCTURE ICING: NON-SUITABILITY OF CURRENT FORECASTING AIDS FOR NAVY SHIPS

## INTRODUCTION

The Oceanography Command of the U.S. Navy is currently directing efforts to develop computerized aids for local use by navy environmental officers aboard ship in analyzing and forecasting various atmospheric and oceanographic conditions. These aids are intended to free the environmental officers from tedious and labor intensive chores such as hand-plotting and analysis of soundings, as well as to enable the production of specialized forecasts which are not practical without the use of a minicomputer. These development efforts are part of three interrelated programs known as the Tactical Environmental Support System (TESS), Shipboard Numerical Aid Programs (SNAP), and Geophysics Fleet Mission Program Library (GFMPL).

The author has been involved in these efforts by preparing computer codes for automated graphical and display aids to be used in the analysis and forecasting of aircraft icing and shipboard superstructure icing conditions. Icing on the decks and superstructure of vessels may occur from blowing spray in windy conditions when the air temperature is below freezing. It may also occur due to bow spray in heavy seas and subfreezing air temperatures.

A dozen or so major studies have been done in the past on the hazards, occurrences, climatology and forecasting of superstructure icing. Most of these studies concentrated on the plight of fishing trawlers because these vessels, as a class, have been most frequently exposed to icing conditions. The effects of icing are greater the smaller the vessel, with capsizing due to accumulated topside weight being the greatest hazard.

There are three forecasting aids (graphs, or nomograms) currently available as a result of some of these studies. But the data base from which these aids were derived consists of icing reports from a mix of vessel types and sizes, most of which appear to be these fishing trawlers. Therefore, it is not clear at all that these forecasting aids even apply to navy ships, except perhaps for a few types that are similar in size to the trawlers.

Since naval operations are usually staged in areas where the hazards and complications of these environmental conditions can be avoided, there appears to be very few reports of icing occurrences on navy ships. However, there is an increasing importance for submarine tracking, and potential antisubmarine operations, in the northeastern Atlantic, for example. Future mission requirements may place surface vessels more frequently in these areas where superstructure icing can occur. Therefore, even if superstructure icing has been unimportant in the past, it may become more important in the future.

The object of this report is to be briefly describe the available forecasting aids, review the most recent work on the topic of superstructure icing, and to recommend a research plan for improving the icing forecast aids for applicability to naval vessels.

Manuscript approved May 4, 1984.

## STATUS OF AVAILABLE FORECASTING AIDS

As of this writing there are three, known, published graphical aids for assessing or forecasting superstructure icing intensities due to wind blown spray. These aids, sometimes called "nomograms", are based on reported cases of superstructure icing and they relate ice accretion intensity to observed or forecast surface air and sea conditions. These three aids are described briefly as follows.

### Diagram Due to Sawada.

This forecasting aid [1,2] is the oldest and simplest of the three listed here. As is shown in Fig. 1, it relates icing severity in qualitative terms to surface air temperature and windspeed. This aid is applicable to fishing trawlers and other small vessels susceptible to capsizing under the weight of severe ice accretion. Many of the vessels Sawada lists [3] as having sunk due to icing are fishing boats with displacements less than 200 tons.

It will be noted in Fig. 1 that the indicated icing intensity is very sensitive to windspeed at low temperatures, and to temperature at high windspeeds.

### Diagrams Due to Mertins.

These forecasting aids [1,4] shown in Fig. 2 are the second oldest of the three. They are more complicated than Sawada's because they take into account the additional variable of sea surface temperature (SST). There is some disagreement [1] as to the need for SST in forecasting aids for superstructure icing, however. Mertin's diagrams apply to the bow and superstructure of relatively large stern trawlers moving at slow speeds, and to some "cargo" ships. As a forecasting aid, there is still considerable sensitivity to errors in the forecasted variables [1]. For example, if the forecast is for windspeed = 8 ± 1 Beaufort, SST = $1^{o} \pm 1^{o}C$, and air temperature = $-4 \pm 4^{o}C$, the predicted icing severity would be anything from <u>none</u> to <u>severe</u>!

### Diagrams Due to Wise and Comiskey.

These forecasting aids [5] in Fig 3. are the newest and most complicated of the three listed here. They are an integrated version of Mertin's diagrams which have been specifically adjusted for conditions in the northeast Pacific as determined by climatological considerations and some 50 icing reports from that area. These reports are from a mix of vessels, including a semi-submersible drilling platform which supplied 25% of the reports.

## RECENT WORK ON SUPERSTRUCTURE ICING

Listed in reverse chronological order are the known research projects which are currently underway or which have been done during the past ten years.

Naval Ship Research and Development Center, Bethesda, MD (1984)

Principal Investigators: G. Neuschafer and CDR L. Elliott

Description of Research: Direct Observational study of ice accretion effects aboard navy ships (DDs, FFGs) in the north Atlantic; development of computer programs to relate ship motion and loss of stability to on-deck ice accumulation for various types of ships.

University of Alaska (1980-1984)

Arctic Environmental Information and Data Center,

Principal Investigators: J. L. Wise and A. L. Comiskey [Ref. 5]

Description of Research: Performed a literature search, collected some 50 icing reports in Alaskan waters and revised Mertin's diagrams for use in the northeast Pacific Ocean. Current work extends the study to include 90 more icing reports.

Naval Research Laboratory, Washington, DC (1983-1984)

Principal Investigator: R. K. Jeck

Description of Research: Survey of recent research in superstructure icing; design of computer program for automated, wide-area, superstructure icing forecast/analysis display product for U.S. Navy TESS application; preliminary feasibility study for obtaining archived ship icing reports from the National Climatic Center, Asheville, NC, and from U.S. Coast Guard cruise reports.

Occidental College, Los Angeles, Calif. (1983-1984)

Principal Investigator: T. L. Kozo [Ref. 8]

Description of Research: Developed contour maps of monthly average and extreme icing conditions for the Bering Sea using climatological data for the area in relation to Wise and Comiskey's nomograms. Kozo's work also takes into account the climatological distribution of sea ice which substantially reduces wind blown spray when the areal coverage of the sea by ice is of the order of 50% or more.

University of Pennsylvania, Philadelphia, PA (1983-1984)

Principal Investigator: Prof. B. Gebhart

Description of Research: Computer modelling of the freezing process for salt spray. Studies concentrate on the role and fate of salt and other impurities in the brine droplets upon the transition to pure-water ice during the freezing process.

The Ship Research Institute of Norway (NSFI), Trondheim, Norway (1983-1984)

Principal Investigator: Sveinung Løset

Description of Research: A project called "Exploration of Anti-Icing and De-Icing Methods for Marine Application" is underway to identify methods of prevention and removal of ice from ship and drilling rig superstructures.

U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH (1977)

Principal Investigator: D. L. Minsk [Ref. 6]

Description of Research: Performed a literature search, reviewed conditions affecting the intensity of ice accumulations, presented climatological maps of the geographical occurrence of icing, developed equations for computing the amount of ice that may form on test probes proposed for use in quantifying and standardizing ice accumulation reports.

Naval Air Propulsion Center (NAPC), Trenton, NJ (1977)

Principal Investigator: K. T. Swan [Ref. 7]

Description of Research: Surveyed literature to define hydrometeorological conditions conducive to icing of gas turbine inlets on ships. Directed an analysis of windspeed and air temperatures from ship reports archived at the National Climatic Center (Asheville, NC) to develop frequency-of-occurrence maps for probable icing conditions in the North Atlantic.

## RECOMMENDATIONS

Based on the information obtained by the author during this project, the following recommendations are made:

1. Determine Which Types of Navy Vessels are Actually Susceptible to Superstructure Icing From Wind Blown Spray and From Bow Spray.

The susceptibility of a given type of ship evidently depends mainly on the freeboard at the bow, and in some cases at the fantail or amidships. Ships with very high freeboards (e.g., CVs, LPHs) may be insignificantly affected by icing from blowing spray. Intermediate sized ships (eg., FFs,

DDs, CGs) may be more susceptible, especially to bow spray. Small craft (e.g., patrol, service, and combatant vessels) are obviously the most susceptible, The currently available forecasting aids illustrated in Figs. 1-3 may be reasonable guides for these small craft but maybe not for the intermediate sized ships.

In any case there will be uncertainties in applying any forecasting aid unless the aids can take into account differences in the height of the freeboard among various ship types, the applicability to the bow or fantail (helo pad) sections of the ships, and the heading of the vessel relative to the wind and waves.

2. Determine the Quantity and Availability of Ship Icing Reports Archived at Various Record Centers.

The relevant record centers include those maintained by the National Climatic Center (NCC), the U.S. Navy, the U.S. Coast Guard (USCG), NOAA, merchant marine companies, and national weather records centers of foreign countries.

3. Proceed with at Least a Small Scale Program to Develop a Computerized Data Base of Ship Icing Observations.

In particular, the goals of such a project should include:

a. Search readily available sources, such as "The Mariner's Weather Log" and "The Marine Observer" for ice accretion reports.

b. Obtain a complete search of the ship reports archived at NCC.

c. Search the USCG ships logs and cruise reports.

d. Determine the feasibility of obtaining icing reports from logs or other records from U.S. Navy vessels.

e. Determine the feasibility of obtaining and reprocessing ship icing reports used by earlier investigators (e.g., Japanese, Canadians, British, Russians) who have produced technical reports or journal articles on the subject.

f. Compile all available data into a computer compatible medium for re-analysis. If a sufficiently extensive data base is developed, it may be possible to perform analyses which take into account ship size or displacement, and freeboard, and which also provide an account of the types and locations of U.S. Navy ships which have reported icing conditions.

## Progress

With regard to the second recommendation above, the author's preliminary study has produced the following information.

a. <u>Ship Icing Reports Archived at the National Climatic Center (NCC), Asheville, North Carolina.</u>

Icing reports are likely to be infrequent because:

I. Optimum ship routing tends to keep ships away from the worst storm track areas.

II. Shipboard weather observers are reportedly seldom motivated to report icing events unless the events are unusually severe or long-lasting. In the latter case, an eventual report may not reveal how long icing had been occurring prior to the report.

III. Even if icing events are recorded in the columns provided on the standard WMO ship report form, these columns are not transmitted on the international telecommunications-network for weather data distribution. At best, these observations are retained in the archived ship reports of the country of registry or of the country in which the shipping company offices reside, whichever receives the radio messages from the ship. Thus, NCC should retain the complete weather observation reports f ships of U.S. registry, but not from any foreign ships. One would hav o inquire at the Norwegian meteorological service to obtain reports from ps of Norwegian registry, for example.

To check the availability of ship icing reports at NCC requested via NAVOCEANCOMDET (Asheville) a trial search of the NCC archives for reports containing icing observations from ships in the North Atlantic. The first search was of reports from only the weather ships (OSVs). The reasoning was that if icing occurred on these ships, it was more likely to be reported than on non-OSV ships. Also, higher quality reports would be expected from the trained observers aboard the OSVs.

No icing observations existed at NCC for the foreign operated OSVs (A, C, D, and P) because of the aforementioned problem that the international data exchange format does not provide space for reporting ice accretion. However, records from OSV "B", positioned near 56.5°N and 58.5°W (in Marsden square 186), did contain 132 ice accretion observations for the sampled reporting period of 1967 through 1972. These 132 observations were distributed by month as follows: Dec (2), Jan (54), Feb (41), Mar (35). The sum of reports collected from OSV "B" during the sampled reporting period numbered about 6000 for each month.

Encouraged by this result, we next decided to conduct a trial search of non-OSV reports from Marsden square 184 (50°-60°N, 30°-40°W). This area is at the same latitude as OSV "B" but is more astride the North Atlantic shipping lanes. A search of just the month of January during the period 1970-79 yielded only 8 icing observations out of a total of 5674 reports. However, a continued search of 4 or 5 other likely Marsden squares in the North Atlantic for a longer sampling period and for the other three winter months may yield a useful amount of data.

There are other geographical areas to be searched too --- namely the Northern Pacific and the U.S. Great Lakes regions.

b. Ship Icing Reports From the U.S. Coast Guard (USCG).

The Ice Operations Division of the USCG Safety Programs Office in Washington, DC, retains the cruise reports from USCG vessels. These reports summarize the cruise and mention or describe any significant events, including superstructure icing. The actual ship's logs are retained elsewhere. The logs contain the hourly weather observations, including superstructure icing if the meteorological officer regarded the icing as significant.

Both of these sets of records may be good sources for superstructure icing data on intermediate sized ships such as cutters and icebreakers. Contrary to trans-ocean merchant ships which may elect to avoid routes through severe weather, the nature of the USCG mission tends to expose its vessels to severe weather more frequently. Also, the quality of icing reports from USCG vessels is likely to be better than from merchant ships.

c. Ship Icing Reports From U.S. Navy Vessels.

The amount and accessibility of icing reports from U.S. Navy vessels has not yet been investigated. The impression is that except for occasional cold weather exercises, most Navy operations take place well away from areas where complications from superstructure icing could arise. There may be some data available from logs of ships taking part in the cold weather exercises, or which routinely operate near cold weather ports such as Keflavic, Iceland. However, in peacetime, at least, willful exposures to icing conditions are probably rare.

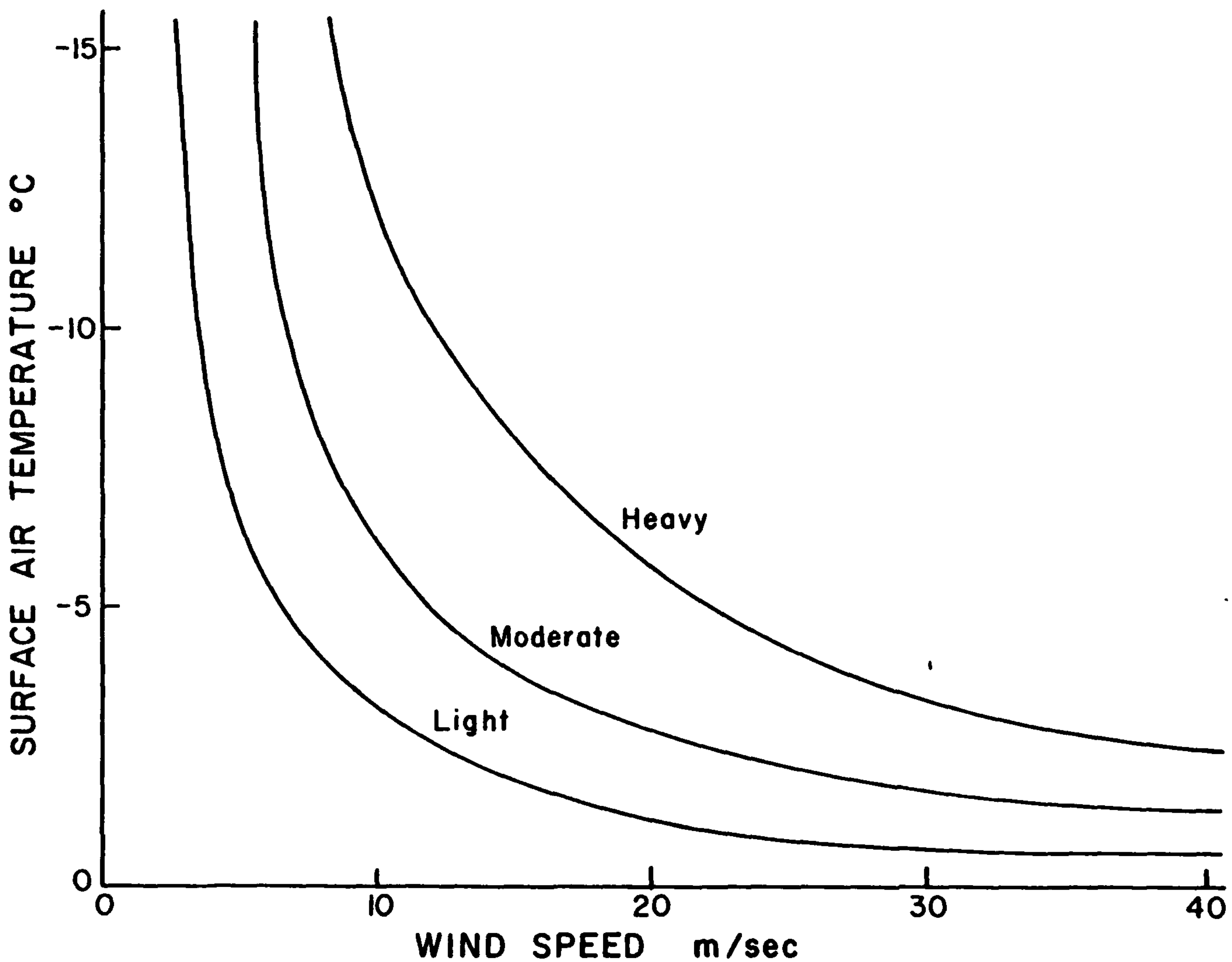


Fig. 1. Sawada's diagram relating icing on ships to surface air temperature and windspeed.

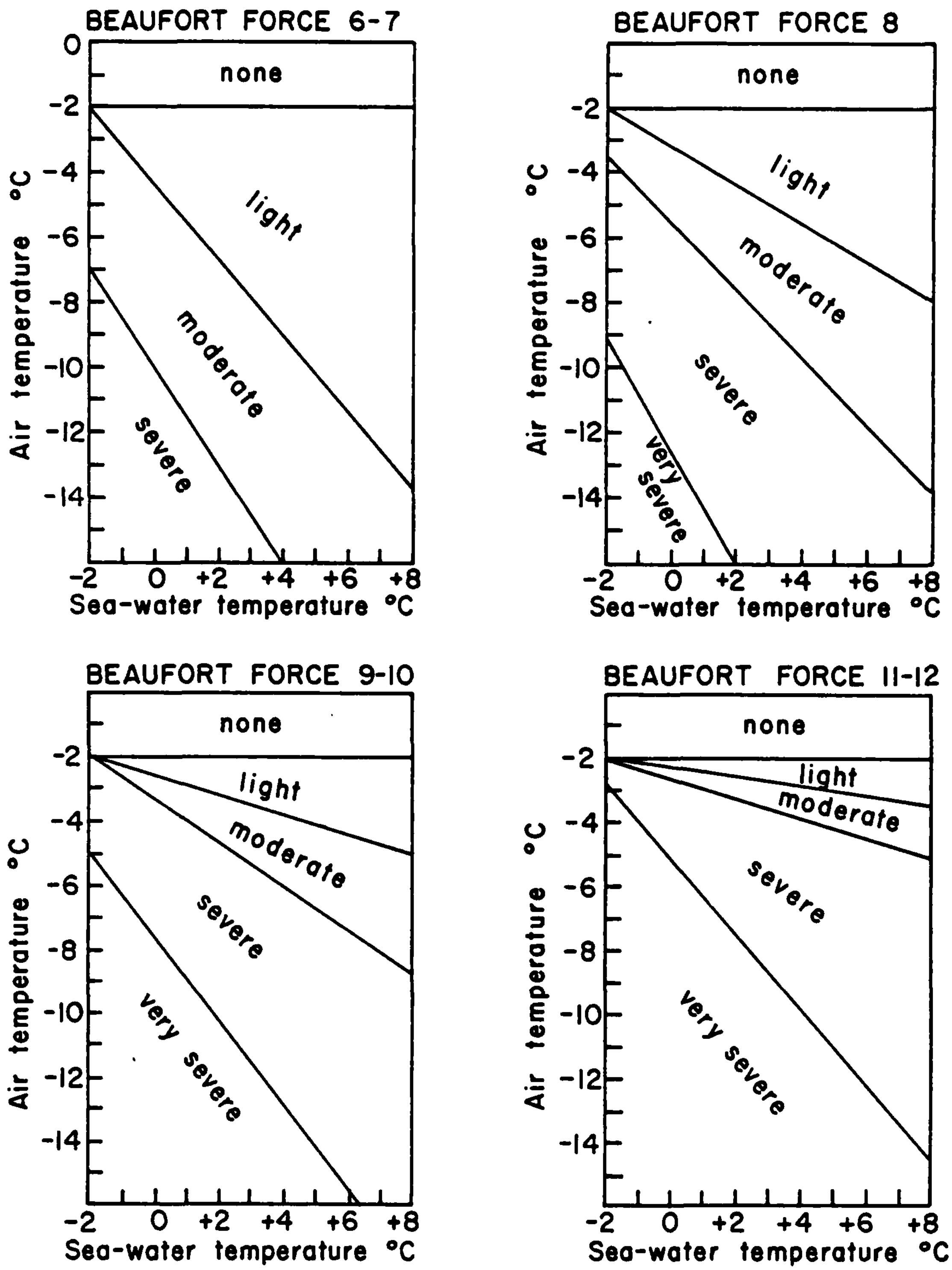


Fig. 2. Mertins' diagram for icing on low speed fishing vessels. Icing intensities are defined in terms of the following accumulations per 24 hour period: light = 1-3 cm, moderate = 4-6 cm, severe = 7-14 cm, and very severe ≥ 15 cm.

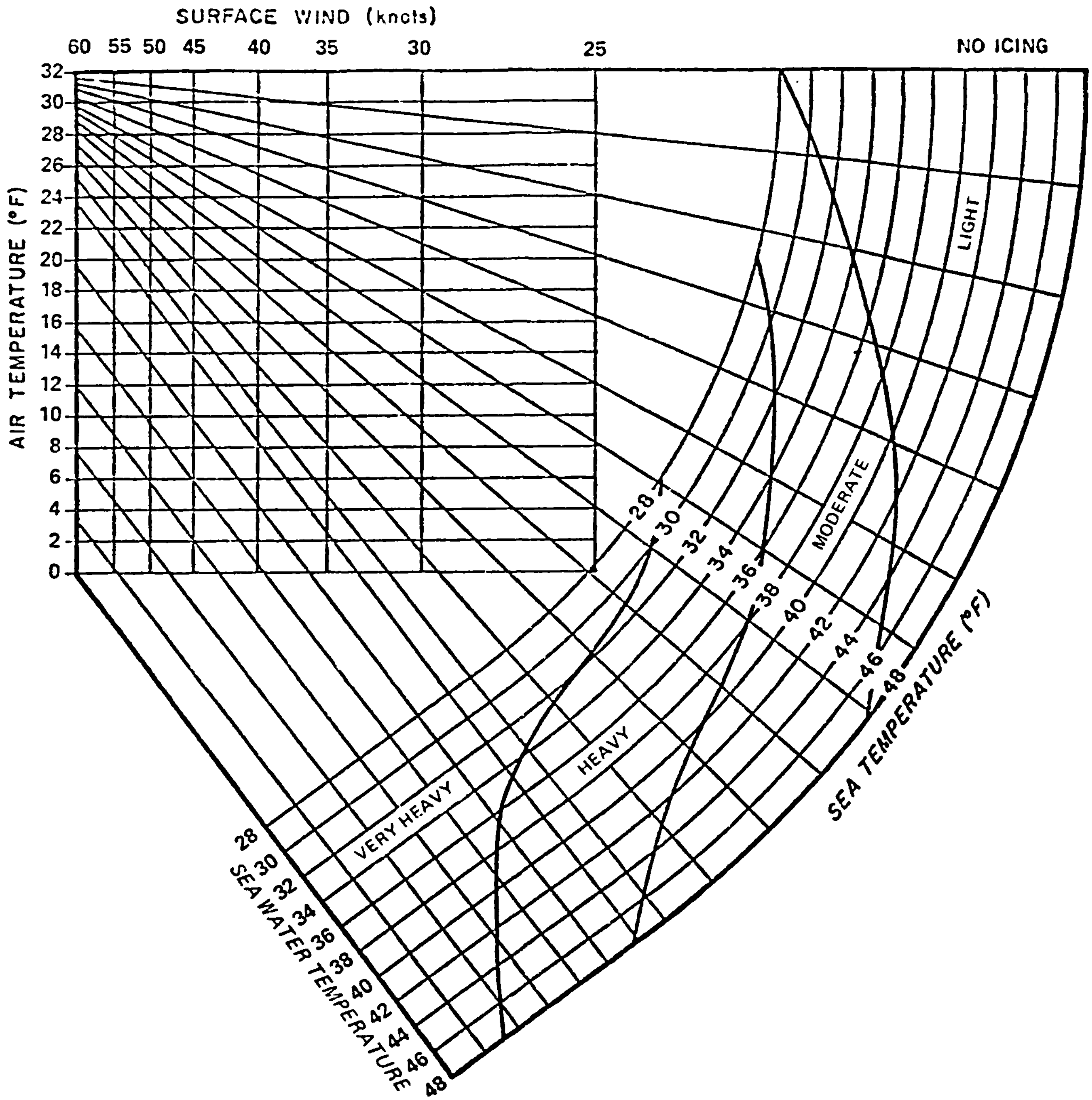


Fig. 3. One form of Wise and Comiskey's nomograms. Icing intensities are defined in terms of the following rates of accumulation per three hour period: light = 0.05-0.2 in., moderate = 0.2-0.3 in., heavy = 0.3-0.75 in., very heavy > 0.75 in.

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